COPPER AS AN ESSENTIAL FOR PLANT GROWTH[1]

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(WITH THREE FIGURES)

The stimulating effect of copper on plant growth was noted early in the use of copper salts as fungicides. A few years ago FELIX (**3**) obtained improvement in the growth of certain plants on several peat soils by the application of copper sulphate, both to the soil and in solution to the leaves. ALLISON, BRYAN, and HUNTER (**1**) were able, by the use of copper sulphate, to produce crops on certain otherwise unproductive peats of the Florida Everglades. Other treatments, notably caustic lime, manganese sulphate, and manure also gave improvement, but were not so beneficial as copper sulphate. BRYAN (**2**) also obtained greening in chlorotic leaves of plants grown in this soil by treating them with solutions of copper sulphate or manganese sulphate. These investigations do not furnish final proof, however, that copper is essential to plant growth. The work reported in this paper provides additional evidence on this point.

Sunflowers, tomatoes, and flax were used in these investigations. One-liter pyrex beakers with paraffine-coated, plaster of Paris covers were used as containers for the solutions in which the plants were grown. All water used in making up the nutrient solutions was redistilled from pyrex. In the first experiment with sunflowers the salts used had been repurified for an earlier study (**5**) on the effects of the absence of boron on plant growth. These salts had been recrystallized from water from a copper still; this still had the usual block tin condenser. In later experiments the water used for the purification of the salts was redistilled from pyrex. The methods used for the repurification of the salts[2] are described in a previous paper and will not be reiterated here.

The solutions to which copper was or was not added had the following composition:

[1] Presented before the Division of Biological Chemistry at the 78th meeting of the American Chemical Society, Minneapolis, Minn., Sept. 9–13, 1929.

[2] Analyses made recently in the laboratory of Professor FRED ALLISON (see Journal of the American Chemical Society 52: 3796–3806. 1930, for method) on samples of some of these salts showed that copper in a concentration of about 5×10^{-11} was present in the solutions because of copper added as an impurity of the KNO_3, KH_2PO_4, and $MgSO_4$. Unfortunately samples of the other salts and the distilled water used were not available so that the total copper concentration of solutions to which copper was not intentionally added could not be determined. The amount added as impurities in the salts must, however, have been very small.

	per liter		per liter
KNO_3	0.80 gm.	$MgSO_4 \cdot 7H_2O$	0.50 gm.
KH_2PO_4	0.15 "	$CaSO_4$, saturated solution, 300 cc.	

Iron was added in the form of $FeSO_4$ as the plants needed it. In the work with sunflowers, traces of the following elements were also added: manganese, aluminum, iodine, fluorine, sodium, chlorine, and boron. In addition to these, traces of tin, rubidium, lithium, barium, mercury, nickel, cobalt, arsenic, and lead were added to the cultures of tomatoes and flax. An excess of SiO_2 was added in all cases.

Dwarf sunflowers were used as experimental plants in the first investigation. The cultures were divided into two groups, one with and one without copper. Five cultures of two plants each were included in each group. Copper, as copper sulphate, was added to the solutions receiving copper at the rate of 0.125 mg. per liter. Two subsequent additions, one of 0.125 mg. and one of 0.06 mg. were made.

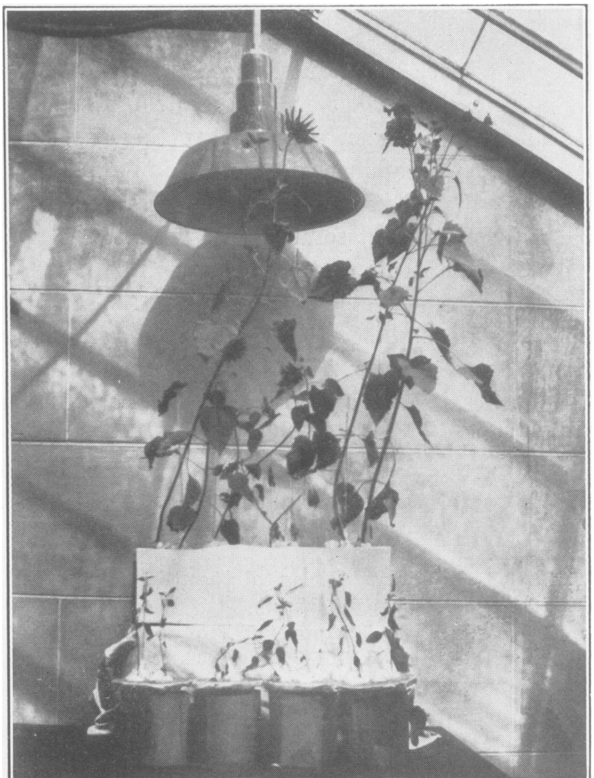

FIG. 1. Sunflowers grown with and without copper. Upper row with copper; lower row without copper.

The plants were transferred to the experimental solutions while in the cotyledon stage. By the end of the week, the plants in solutions containing copper began to show better growth than those without copper. Although very variable in size, those receiving copper appeared normal, and all were blooming at the time of harvest. Only one plant without copper produced a bud which was very small and appeared abnormal. The average dry weight per plant of those receiving copper was 4.2 gm.; that of the plants without copper was 0.31 gm. Plants grown with and without copper are shown in figure 1.

Sunflowers of a second series did not do so well. The reason for the poorer growth was not determined. Conditions which might have been causative, however, were: (1) the culture solutions became overheated when the temperature control of the conservatory was out of order, and (2) the salts used in the preparation of the nutrient solution were repurified from water redistilled from pyrex; consequently they may have been free from impurities which may have been beneficial to the plants of the preceding series. With the exception of one plant, those without copper were noticeably poorer within three weeks than those with copper. This plant appeared similar to the control plants for several weeks, and was as large as some of them when harvested. About the time it produced a bud, a little later than most of the control plants, it began to appear to be a very sick plant, and the bud did not develop. The average dry weight of plants without copper was 0.16 gm. Four plants were dead and the rest were in very poor condition. The average weight of plants with copper was 0.70 gm. The tops of these plants appeared normal, but the roots, like those of the plants without copper, were badly infected with fungi. Copper was added in this experiment at the rate of 0.06 mg. per liter. Four additions were made during the experiment.

Tomatoes (Dwarf Champion) were used as experimental plants in a subsequent investigation. This series was divided into two groups of six cultures each, one group with and one without copper. There were three plants to each culture. A single addition of 0.06 mg. copper per liter of solution was made to each of the six cultures with copper.

The plants were transferred to the experimental solutions in the cotyledon stage. All plants grew well for the first week. Soon after this, some of the plants without copper began to appear sickly; two were dead by the end of the second week; by the end of the third week a third plant had died. All plants with copper made good growth until the beginning of the seventh week, when one of the plants wilted; this plant was in very poor condition when the plants were harvested at the beginning of the ninth week. Most of the plants with copper had buds, and all except the one mentioned were in excellent condition. The average green weight

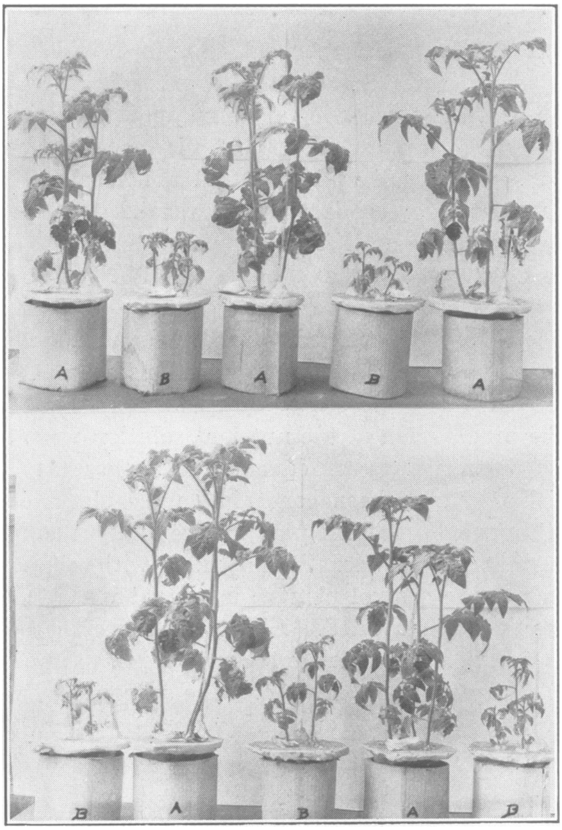

FIG. 2. Tomatoes grown with and without copper. Cultures (A) grown with copper; cultures marked (B) grown without. Only 0.06 mg. copper per culture was used.

of plants without copper was 2.9 gm.; that of plants with copper was 31.3 gm. The average dry weight of plants without copper was 0.3 gm., while that of plants with copper was 2.6 gm. The average did not include the three plants without copper which had died nor the one with copper which was badly wilted. The plants at time of harvest are shown in figure 2.

It is well known that copper is toxic to green plants even in relatively low concentrations. It was found by the writer in earlier work that there was considerable inhibition of root development for some plants at a concentration of 0.25 mg. per liter. It is, therefore, not surprising that a single addition of 0.06 mg. of copper would determine whether three plants would produce, as the largest culture did, 142.2 grams of green matter as compared with 12.8 grams, the weight of the largest culture without copper.

Moreover, it remains to be determined how small an amount of copper will be sufficient to produce an adult tomato plant.

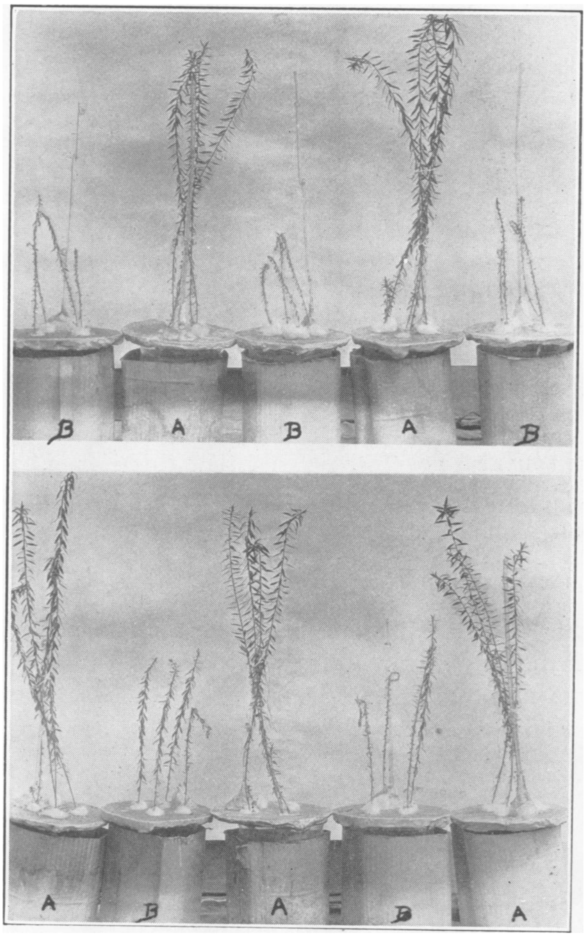

FIG. 3. Flax grown with and without copper. Cultures (A) grown with copper, cultures (B) without.

Flax was the third plant investigated. As in the previous experiments the plants were transferred in the cotyledon stage to the solutions to which copper had or had not been added. All plants grew well for the first week. By the middle of the second week the plants without copper were noticeably smaller than those with copper. About the end of the third week the roots of all plants appeared somewhat abnormal, and the plants with copper seemed to be growing more slowly than before. A second addition of 0.06

mg. of copper was made to each of the cultures with copper. Because this addition apparently was of no benefit, an addition of traces of all elements previously used in very small amounts was made to all cultures (cultures without copper as well as those with copper) a week later. The plants with copper began to show improvement within a few days, but those without it appeared to make no further growth. Six of the plants were dead at the time of harvest, fifty-two days after they were transferred to the experimental solutions. Most of the plants with copper had buds at this time but were not of normal size, as were plants grown at the same time in solutions of salts of ordinary purity. This indicates that flax has a larger requirement for one or more of the elements added in traces than does the tomato plant. The dry weight of eighteen plants without copper was 1.4 gm.; that of the same number of plants with copper was 4.5 gm. Plants grown with and without copper are shown in figure 3.

The investigations of Felix, of Allison, Bryan, and Hunter and of Bryan, even though showing very beneficial effects of applications of copper, did not furnish conclusive proof that this elements is essential to plant growth. Smith (**4**) has shown that there is a toxin in the black moor soils (Gliede) of Holland which prevents normal plant growth, and which is rendered non-toxic by copper sulphate. It may be, therefore, that the beneficial effects obtained by the above mentioned investigators were due to a similar chemical action in the soils when the reagents were applied to the soils, or in the leaves when they were treated with solutions of these reagents. Bryan showed greening of spots on chlorotic leaves where solutions of copper sulphate or manganese sulphate had been applied. A manganese deficiency is known to produce a certain type of chlorosis, but plants which were grown in solutions of purified salts to which no copper had been added were never chlorotic at any stage in their growth or decline. We have as yet no clew as to what the rôle of copper in plant metabolism may be, but the idea that it may act as an autooxidant is intriguing since it is well known that an extremely small trace of this element will act as a catalyst, greatly hastening the process of rancidity in fats. This catalytic property may also explain why both copper and manganese salts are so beneficial when applied to certain organic soils.

I wish to express my appreciation for the aid and encouragement which I received from the late Professor J. Arthur Harris in this work during my sojourn at the University of Minnesota.

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